Imperial College London

Institute for Molecular Science and Engineering

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# Smart surfaces to tackle infection and antimicrobial resistance

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## Headlines

### Issues

- Contaminated surfaces and medical devices contribute to the transmission of healthcare-associated infection (HCAI) and the spread of antimicrobial resistance (AMR). A 2016 survey in England found that 6.6% of hospital patients acquired HCAI.
- Surface-attached biofilms (communities of microbial and non-microbial matter on surfaces) support microbial survival, persistence, and can protect microbes from attack by biocides and antibiotics.
- Infection pathways include medical devices, surgically implanted prostheses, touchpoints in the clinical environment and hospital water systems.
- These pathways are increasingly recognised in the transmission of pathogens that can cause HCAI and increase AMR.

### Solution

- Antimicrobial surfaces could disrupt the microbial habit by reducing microbial attachment and/or killing attached microbes.
- The design, manufacture and testing of antimicrobial surface technologies must involve multidisciplinary teams from molecular science, engineering, medicine and business.
- Antimicrobial surfaces should be developed with low and middle-income (LMIC) settings in mind, where these surfaces could mitigate the impact of challenges such as lack of power and clean water.
- Antimicrobial surfaces should employed as part of a combined approach involving clinical and cleaning protocols, and the responsible distribution and use of antibiotics.

## Introduction

Many patients acquire a healthcare-associated infection (HCAI) in hospital. The most common types of HCAI are respiratory infections (including pneumonia and infections of the lower respiratory tract) (29.2% of all HCAI), urinary tract infections (17.4%) and surgical site infections (15.0%). Each one of these infections means additional use of National Health Service (NHS) resources, greater patient discomfort and a decrease in patient safety.

The misuse and overuse of antibiotics has resulted in the development and spread of antibiotic-resistant bacteria. These infections are already costing 50,000 lives each year in Europe and the US alone. Unless new solutions are developed, global costs are estimated to reach US $3Tn annually by 2050 and an additional ten million people could die each year.

Molecular science and engineering approaches can be employed to develop "smart" surfaces that could reduce microbial attachment, actively destroy microbes, and disrupt the microbial habitat. Such antimicrobial surfaces have the potential to provide effective, low-cost solutions to combat microbial contamination, transmission and antimicrobial resistance.

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## Why should Government, the National Health Service, and medical device companies invest in antimicrobial surfaces?

- Conventional approaches are not sufficient to tackle biofilms and surface attached cells.
- Smart surfaces minimise health and safety risks by reducing the risk of infection and the need for chemical disinfectants.
- Smart surfaces could lower costs of treating infection and routine cleaning.
- Regulatory changes are limiting the use of previously widely employed biocidal agents and biofilm control approaches due to concerns about environmental pollution and toxicity.
- Consumer pressure is leading to industry-wide use of more sustainable and naturally-derived ingredients in manufactured products.

## Ideal properties of an antimicrobial surface to be considered in the design stage

| **Characteristic** | **Criteria** |
|---|---|
| Safe | For regular contact with patients, staff and visitors, including for sensitive areas and broken skin. |
| Healthcare Economics | The associated additional costs must be balanced by resultant cost savings. |
| Simple application technology | Ideally put in place during manufacture or applied as liquid agent. |
| Long term | Active for months or years, without the need for re-application. |
| Rapid antimicrobial activity | In seconds or minutes (rather than hours). |
| Prevention of biofilm formation | e.g. through oxidation or modification of the physical structure of a surface. |
| Compatibility with current cleaning and disinfection products. | Neither in the short or long-term. |
| Retention of activity with low-level soiling. | Likely to depend on the type of surface. |
| Does not promote clinically-significant resistance or reduced susceptibility. | This is a theoretical risk: there is currently no specific evidence for this. |
| Sporicidal activity. | To avoid providing a selective advantage to *C. difficile*. |

## Candidate antimicrobial surface types

### 1. Altered surface topography

The properties of a surface make it less able to support microbial contamination and/or easier to clean. This avoids the use of anti-bacterial chemicals so bacteria cannot adapt and become drug resistant.

- Surfaces can decrease the viability of surface-associated microbes. Cicada wings have nanoscale spikes that can puncture the cell walls of bacteria. Metal organic framework (MOF) surfaces with nanoscale spikes have been shown to have antibacterial properties. Organosilane-coated surfaces may or may not have the same properties.
- Anti-adhesive surfaces can also use micro scale roughness (1 to ≤1000µm) to decrease microbial attachment. Sharklet™ surfaces mimic the approximate topography and geometry of shark skin and inhibit growth and biofilm formation solely through surface design. It significantly reduces surface contamination high touch surfaces and catheter tubes.

### 2. In-built and slow-release antimicrobial agents

An agent with antimicrobial activity is an intrinsic part of a surface or an agent is engineered for gradual release.

- Copper alloys have demonstrated *in vitro* activity against a range of pathogens, and have been effective at reducing healthcare associated infections. They have proved effective against fungal infection in hospital environments. The longterm safety, durability, acceptability and cost-effectiveness of the use of copper alloys as antimicrobial surfaces has not been formally evaluated. The price of copper is likely to be prohibitive for wide-spread use.
- Silver has been shown to be toxic to a wide range of pathogens. Silver alloy reduced incidence of infections from catheters, and silver nanoparticles reduced the risk of microbial contamination of water.

### 3. Self-cleaning and self-polishing surfaces

- Titanium dioxide ($TiO_2$) is a photocatalytic surface: it absorbs light and generates hydroxyl free radicals which kill bacteria by attacking the cell membrane. Titanium dioxide has been successfully used as an antimicrobial coating for ceramic tiles or silicone catheters, and in water decontamination. Photocatalysts are especially effective in the hospital environment due to their self-regenerating biocidal effect that makes such surfaces active for long periods of time.
- Many plant extracts are well known for their antimicrobial properties. There is limited evidence that tea tree oil reduces biofilm formation on medical devices.

## The need for a multidisciplinary approach

For rapid innovation to address infection and antimicrobial resistance, we need to integrate molecular science with engineering, medicine and business. Exploiting the latest molecular science and engineering solutions for antimicrobial surfaces whilst considering the manufacture, distribution and overall costs of a solution is challenging. Imperial College London has world leading subject matter experts in infectious disease, its transmission and epidemiology; medical devices; the understanding of biofilms; the physics, chemistry and engineering of nanomaterials; theory modelling and simulation; and the generation of innovative sustainable business systems.

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